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SOLAR ACTIVITY AND RADIO RECEPTION

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[Perkins Observatory, Ohio Wesleyan University, Delaware, Ohio, May 27, 1932]

With the accumulation of solar observations, the study of the sun as a factor in the study of meteorological phenomena appears increasingly fruitful in scientific investigations. Close cooperation of the Weather Bureau with the United States Naval Observatory and the Yerkes, Mount Wilson, and Perkins Observatories makes possible the publication of data of the condition of the solar surface with scarcely, if ever, a missing date.

Many attempted correlations have been made between the so-called Wolfer sun-spot numbers and meteorological conditions, such as changes in temperature, precipitation, and barometric pressure, some of which are not without marks of significance. Measures in the variation of solar radiation at the Smithsonian Institution and the relative intensity of ultra-violet radiation as recorded at Mount Wilson and the desert laboratory in Arizona provide additional data of growing significance in correlation studies of solar and terrestrial phenomena.

The remarkable work of Douglass [1] in establishing the records of variable periods in precipitation over the centuries as concomitant with the variations in solar activity leave little doubt as to the reality of the ultimate importance of considering solar activity as a factor in climatic changes.

That a new means has become available of studying the correlation of solar activity with atmospheric phenomena through the advent of the radio appears to be rather definitely established through recent researches on the correlation of sun spots with radio reception.[2] The work of Austin,[3] at the Bureau of Standards, and the pioneer work of Pickard have established records of utmost significance. While the work of Austin at the Bureau of Standards has shown less definitely an obvious correlation between the intensity of radio reception and solar activity from measures in the region of long wave lengths, or low frequency, measures in the broadcast band have appeared to indicate most definitely that changes in the intensity of radio reception accompany changes in solar activity as exhibited by the frequency of sun spots.

Work in the broadcast zone was begun by G. W. Pickard [4] in his private laboratory at Newton Center, Mass., in 1926, and was later carried on by the writer at the Harvard Astronomical Laboratory, at Cambridge, Mass. The apparent concomitance in the changes of radio intensities as received from WBBM, Chicago, at Boston, with the inverted curve of sun-spot numbers is clearly shown in the accompanying diagram (fig. 1),

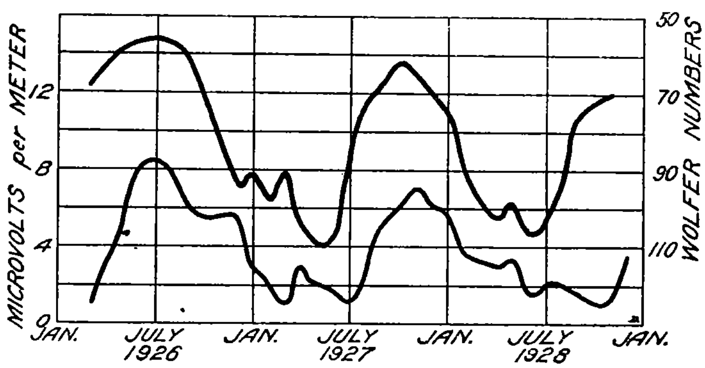

FIGURE 1.—Upper curve shows inverted sun-spot numbers; lower curve, radio-intensity measurements. Observations received at Boston from WBBM, Chicago

covering the years 1926—1928. Secondary peaks in the curve of sun-spot numbers traced over a considerable interval show the persistance of a 15-month subcycle in solar activity, which accounts for the three major peaks in the last maximum of the sun-spot curve. The 1920 peak, accompanied by a marked depression in the radio intensity curve, was predicted by Stetson and Pickard [5] in 1928, and the fulfillment of the prediction seems to give considerable support both to the hypothesis of the 15-month cycle and to that of the correlation of radio transmission with solar activity. It appears that the variation in the intesnity of the carrier wave as received at the recording apparatus may be attributed to a change in the hypothetical altitude of the Kennelly-Heaviside layer from which the sky wave is returned earthwards in long-distance transmission. At distances too remote from the sending station to be seriously affected by a ground wave the reflected sky wave appears to be the dominant factor in determing the intensities of signal strengths.

The most obvious effect of solar radiation upon radio phenomena is the well-known daylight and darkness

[1] Reports of the Conference on Cycles, p. 5. Carnegie Institution of Washington, 1929.
[2] Publ. Am. Astron. Soc., *6*, 244; Pop. Astron., *37*, 388; Journ. of the Franklin Institute, *210*, 4, 414 (October, 1930).
[3] Proc. Institute of Radio Engineers, *19*, 10, 1766 (October, 1931).
Proc. Institute of Radio Engineers, *15*, 2, 9 (1927); Pickard, Proc. Institute of Radio Engineers (December, 1927).

[5] Publ. Am. Astron. Soc., *6*, 244.

effect, which unquestionably is due to the change of ionization level in the earth's atmosphere. One may regard the sun as a hot body continually discharging radiations or corpuscles which, striking the earth's atmosphere, eventually ionize it to a determined level during the hours of sunshine. With the approach of darkness, the ionizing effect of the sun being removed, an association takes place with the result that radio waves penetrate to a much higher level of the earth's atmosphere.

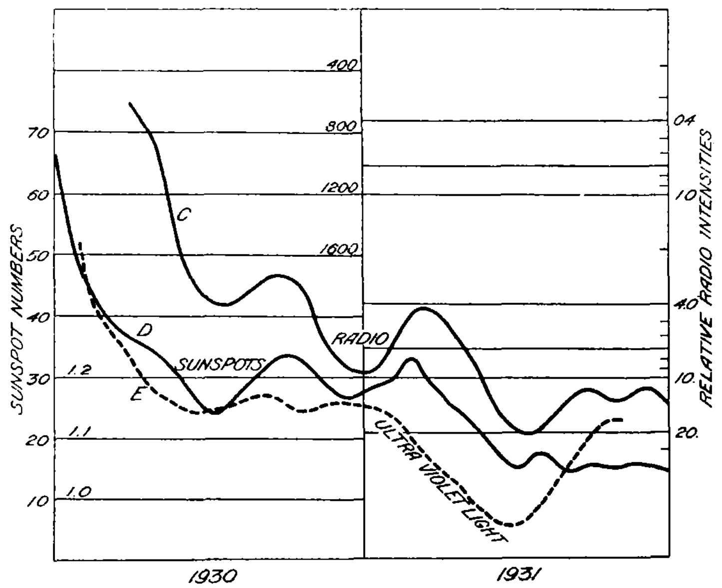

FIGURE 2.—Curve showing sun-spot numbers and radio intensities (logarithmically plotted) from WBBM, Chicago, as received at Perkins Observatory, Delaware, Ohio

If observations of radio reception are made well after the twilight zone is past, one may expect that measures of intensities on a given evening will be an index to the height of this ionization level familiarly known as the Kennelly-Heaviside layer, and the studies of such measures made over a long period of time may be expected to give results as to such periodic changes as may exist in this ionized layer as a function of solar activity. If, in times of high sun-spot numbers, more electrons are emitted from the sun, or if in some way concentrated bundles of electrons are directed earthward, the increased ionization resulting in the earth's upper atmosphere should become observable through changes in the intensity of radio receptivity.

Two hypotheses may be advanced to account for the lowering level of the Kennelly-Heaviside layer with the increase in sun-spot numbers—first, that on account of the general condition of solar activity emission actually rises over the whole sun; and second, that the electromagnetic fields of the sun spots concentrate the stream in the direction of the axis of the cyclonic whirls in the sun spots so that when they appear on the surface of the sun in the general direction of the earth, the earth is subjected to a heavier bombardment of emitted particles, thereby increasing the electron density of the upper atmosphere and effectively lowering the Kennelly-Heaviside layer. Studies of the radio reception records now available seem to favor the second hypothesis, which by no means excludes, however, the first hypothesis mentioned.

With the establishment of a research program at the Perkins Observatory in 1930, automatic recording apparatus, made possible through a grant from the Rumford Committee of the American Academy of Arts and Sciences was set up in the laboratory of the Perkins Observatory and put into operation at the beginning of March, 1930. Meanwhile the series of observations in the region of Boston have been continued through the cooperation of Professor Kenrick, with apparatus at Tufts College, in Massachusetts.

At the present date of writing (April, 1932) two years of observations of WBBM, Chicago, have been received at Delaware, Ohio. The mean intensities in the received carrier wave have been automatically recorded and form the basis for a curve of three months' moving averages, depicted in Figure 2. The ordinates represent for the lower arm in Figure 2 sun-spot numbers based on three months' moving averages, and for the upper curve corresponding values for microvolts in the antenna laid out logarithmically. It will be observed in the upper curve that the numerical values of the ordinates increase downward in order that the radio reception curve may conveniently parallel the sun-spot curve, thus exhibiting the inverse relationship. A glance at the curve shows that while sun-spot numbers have decreased some 50 per cent during the last year, radio reception has increased 400 per cent. The fact that the same general trend of increasing reception with decreasing solar activity appears to be followed over the 300-mile path between Chicago and Delaware, Ohio, as was exhibited over the 900-mile path between Chicago and Boston, suggests that the disturbance of the Heaviside layer through solar activity is sufficiently extensive to draw rather more general conclusions than we had at first dared suppose.

In the apparatus set up at Perkins Observatory the same general type of arrangement has been maintained as was used at Boston. A superheterodyne receiver, schematically shown in Figure 3, feeds through an oxide

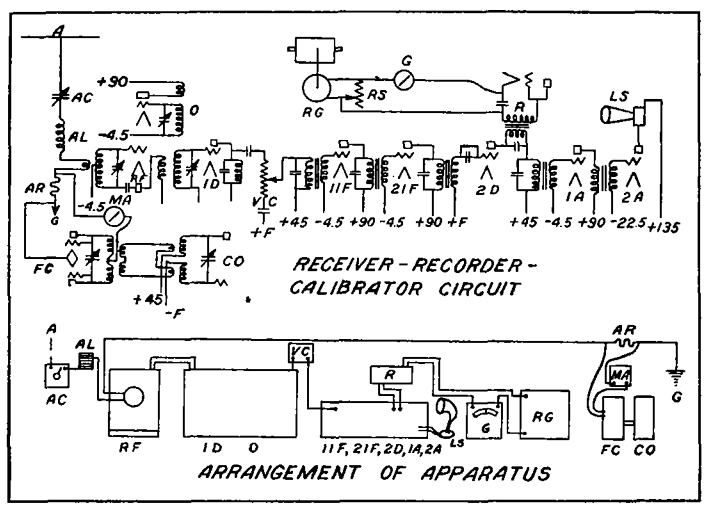

FIGURE 3.—Diagram of radio receiving circuit for recording intensities in the carrier wave

rectifier in the last stage of amplification into one arm of the Wheatstone bridge of the automatic recorder. The automatic recorder employed is of the Leeds and Northrup single-point type in which a compensation for fluctuation in voltage in the unknown arm of the bridge is graphically traced by a pen mechanically connected with the movable contact on a slide wire. The motive power is furnished by a synchronous motor whose motion is communicated to the compensating resistance by the excursions of the needle of the galvanometer connected across the arms of the bridge in the usual way.

To properly standardize the receiving set, including the antenna, a local oscillator tuned to the frequency of the broadcasting station is used each night to propagate a

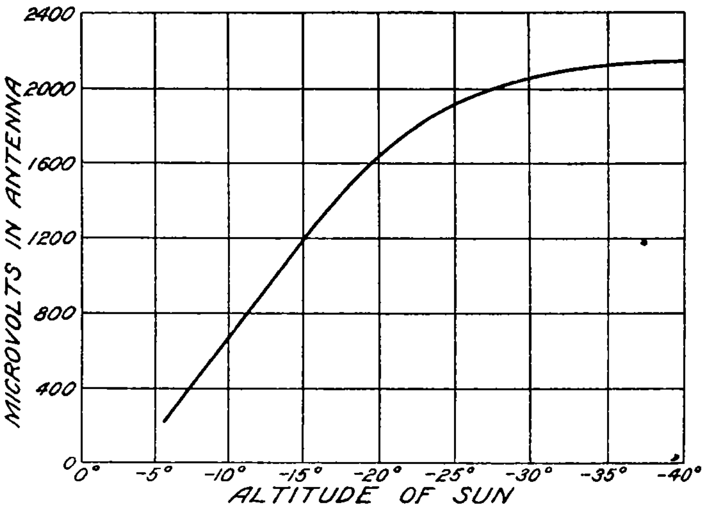

FIGURE 4.—Radio intensity as a function of the sun's distance from the lunar horizon for Delaware, Ohio

wave of known intensity whose measured strength is recorded on the receiving apparatus, thus giving the constant of the apparatus for each night's observations. The deterioration of tubes and the changing resistance of the antenna through varying conditions of weather or humidity therefore does not enter into the reduced values representing signal strengths for a given evening. During the early part of the investigation the observing data have been restricted to the 9 to 10 hour in the evening (E. S. T.), and the averages of signal strengths for twelve 5-minute intervals have been taken from the graph to derive the index of intensities for a given evening.

Inasmuch as the 9 to 10 p. m. hour comes closer to the twilight zone in summer than in winter an investigation has been conducted during the last two years to determine the intensity of signal strengths as a function of the distance of the receiving station from the subsolar point. Various investigators have from time to time studied the changes of signal strength with the change in the solar hour angle. As the varying seasonal change in the declination of the sun, however, materially effects the distance of the observer from the twilight band, it was believed that the correlation of radio reception with negative solar altitudes would more effectively represent a correction curve for twilight effect.

The correction curve given in Figure 4, as a result of an extensive investigation by Mr. Marvin Cobb, of the Perkins Observatory staff, is based on more than 2,000 hours of observation extending over 500 nights from observations made between 9 p. m. and 2 a. m. In arriving at the mean curve in Figure 4 a first approximation has been applied to correct for the general trend of the effect of solar activity during this interval. The application of Figure 4 as a correction curve to the last two years' observations materially changes the curve of directly observed intensities.

In an investigation to determine what effect, if any, the moon may have upon the recorded values of radio intensity, a preliminary study has been made at the Perkins Observatory of observational data of the Cambridge-Boston series of 1926–1929.[6] The curve in Figure 5 is the result of an analysis of these data, which appears to indicate a very considerable correlation between the intensity of radio reception and the altitude of the moon, the altitude of the moon representing the complement of the observer's distance from the sublunar point. The fact that radio intensities appear to be markedly greater when the moon is below the horizon suggests that we have here further means for corrections of radio intensities which may be applied to the curve of radio reception for studying the interrelationship of solar and radio phenomena. A cursory glance at the data in hand suggests at the present writing that corrections for the lunar effect will become significant in further altering the curve of radio intensities which may result in an even closer correspondence of the radio curve with solar activity. Extensive investigations are now in progress at the Perkins Observatory concerning this lunar effect, the results of which will be published at a later date.

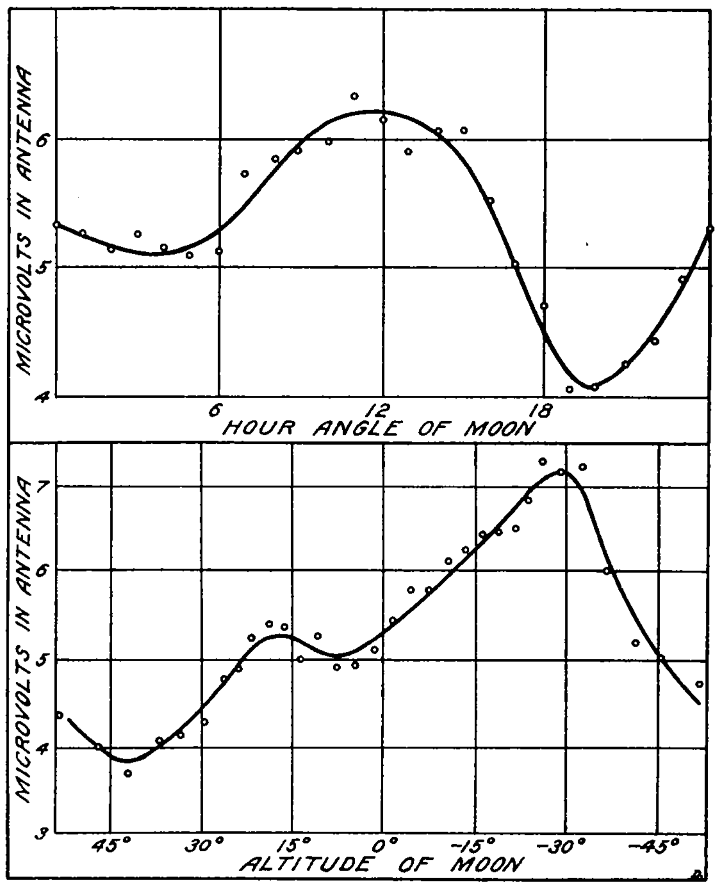

FIGURE 5.—Curves of correlation between the positions of the moon and the intensity of radio reception

Apparatus has now been installed for extending these studies to higher levels of the Kennelly-Heaviside layer through the recording of signals of high frequency from a cooperating station at the Warner and Swasey Observatory, in Cleveland.

[6] Publ. Am. Astron. Soc., 6, 244.